

## **1999 EPA Summary of Refrigerant Reclamation**

The ozone layer is a concentration of ozone molecules in the stratosphere. About 90% of the planet's ozone is in the ozone layer. The layer of the Earth's atmosphere that surrounds us is called the troposphere. The stratosphere, the next higher layer, extends about 6-30 miles (10-50 kilometers) above the Earth's surface. The release of ozone-depleting substances (ODS) into our atmosphere, such as chlorofluorocarbons (CFCs) and hydrofluorocarbons (HCFCs), leads to destruction of the ozone layer. When ODSs are released into the environment, ultraviolet (UV) radiation causes them to break down, releasing free chlorine radicals into the stratosphere, where they subsequently destroy ozone molecules. A diminished ozone layer allows more UV radiation to reach the Earth's surface. Human overexposure to UV rays can lead to skin cancer, cataracts, and weakened immune systems. Increased UV radiation can also lead to reduced crop yield and disruptions in the marine food chain.

By ratifying the Montreal Protocol, complying governments set a schedule for phasing out ODSs, including CFCs and HCFCs. In the United States, this international agreement led to amendment of the Clean Air Act (CAA) in 1990 to include Title VI, Stratospheric Ozone Protection. Section 608 of Title VI, entitled "The National Recycling and Emissions Reduction Program," includes the "Prohibition on Venting" and details legislation that the U.S. Environmental Protection Agency (EPA) follows to create federal regulations on the use, reclamation, and destruction of class I substances (e.g., CFCs), class II substances (e.g., hydrochlorofluorocarbons [HCFCs]), and their substitutes.

In addition to these regulations, the refrigerant purity specifications prepared by EPA under §608 of the CAA are described within Part 82 of the Code of Federal Regulations (CFR) entitled "Protection of Stratospheric Ozone" and are based on the Air-Conditioning and Refrigeration Institute (ARI) 700 purity standard.

In an attempt to minimize destruction of refrigerant and facilitate safeguarding of refrigerant purity, EPA has exercised its regulatory authority issued under the CAA Amendments (CAAA) of 1990 to create a mandatory certification requirement for refrigerant reclaimers. This certification helps to ensure that industry is in compliance with government standards for refrigerant quality and has encouraged development and expansion of the reclamation industry. In this sector, reclaimers offer refrigerant purification and purity verification services to the refrigeration industry. Individuals wishing to transfer ownership of recovered refrigerant must have the refrigerant reclaimed by an EPA-certified reclaimer under the terms of the regulation. Individuals recovering refrigerant (i.e., transferring the product to an external storage container prior to repairing, maintaining, or servicing refrigeration equipment), who are uncertain of the refrigerant's purity, may wish to have the refrigerant reclaimed to ensure its purity before recharging it into refrigeration equipment.

Based upon annual reports from EPA-certified reclaimers, close to 11,900,000 pounds of refrigerant were legally reclaimed in the U.S. during 1999. The remainder of this report provides definitions of reclamation, outlines reclamation processes, provides an overview of reclamation regulations and standards, and describes reclamation and refrigerant destruction technologies and associated costs. A listing of companies that have been certified by EPA to offer reclamation services in the United States is also provided.

## Definitions

The following definitions are provided in Title 40 Part 82 of the United States CFR:

- **Recovery.** To recover refrigerant means to remove refrigerant in any condition from an appliance and to store it in an external container without necessarily testing or processing it in any way.
- **Recycling.** To recycle refrigerant means to extract refrigerant from an appliance and clean it for reuse without meeting all of the requirements for reclamation. In general, recycled refrigerant is refrigerant that is cleaned using oil separation and single or multiple passes through devices, such as replaceable core filter-dryers, which reduce moisture, acidity and particulate matter. These procedures are usually implemented at the field job site.
- **Reclamation.** To reclaim refrigerant means to purify it to at least the purity level specified in appendix A to 40 CFR part 82, subpart F (based on ARI Standard 700, Specifications for Fluorocarbon and Other Refrigerants) and to verify this purity using the analytical methodology prescribed in Appendix A. In general, reclamation involves the use of processes or procedures available only at a reprocessing or manufacturing facility.

## The Need for Reclamation

Reclamation practices are necessary to protect the quality of the refrigerant stock as well as the equipment containing the refrigerant. Additionally, reclamation provides the means to prolong the use of CFCs, as they can no longer be produced or imported into the United States. For example, since the CFC production ban, the availability of pure CFC-12 refrigerant has drastically decreased (from an estimated 42- 48 million pounds in 1999, to an estimated 14.5- 21.5 million pounds in 2000), causing prices to increase by more than 50 percent within the last year (ICF 2000a). The decreasing supply and increasing price of R-12 have rendered the reclamation of this refrigerant highly profitable and essential in helping to sustain its use. This has

provided incentive to develop new technologies that can separate impurities and other refrigerants from mixtures so that they may be re-used instead of destroyed.

Reclamation is also necessary to address situations where refrigerant quality has been severely compromised through equipment failure. For example, compressor failures can severely affect the quality of refrigerant and the lubricating oil. Compressor failures can be caused by low-voltage or poor refrigerant flow situations. In both cases, higher compressor operating temperatures (caused by small electrical shorts in the compressor motor windings) degrade the quality of the refrigerant and lubricating oil. This results in increased acidity of the refrigerant and oil, which subsequently begins to attack components of the refrigeration system itself (i.e., metal parts, valves, and fittings). Therefore, it is critical to recover any contaminated refrigerant originating from compressor failures and reclaim it to remove contaminants before reusing it in the system (ICF 2000b).

## **Statutes and Regulations**

This section provides an overview of the relevant statutes and regulations pertaining to refrigerant reclamation.

### **Clean Air Act Amendments of 1990-Title VI**

#### ***Title VI Section 608-National Recycling and Emission Reduction Program***

Section 608 of CAAA Title VI provides EPA with the statutory authority to establish regulations that reduce emissions of ozone-depleting substances. Regulatory programs developed under this authority include those designed to:

- maximize recycling, recapture, and reduction in the use and emission of CFCs, HCFCs, and their blends to the lowest achievable level;
- set certification requirements for recycling and recovery equipment, technicians, and reclaimers;
- restrict the sale of refrigerant to certified technicians;
- restrict the sale of used refrigerant unless it has been reclaimed by an EPA-approved reclaimer;
- require persons servicing, maintaining, repairing, or disposing of air-conditioning and refrigeration equipment to certify to EPA that they have acquired recycling or recovery equipment; and

- require the repair of substantial leaks in air-conditioning and refrigeration equipment with a charge of greater than 50 pounds.

Section 608 also requires that EPA create standards regarding the safe disposal of class I and II substances. The safe disposal regulations include specific criteria to ensure the following:

- removal of class I and II substances contained in bulk appliances, machines, and other goods before disposal or recycling;
- prohibition of the manufacture, sale, or distribution of any appliance in the United States containing any class I or II substances, unless it is equipped with a service aperture that will allow for the recovery of the substance(s) during service, repair, maintenance, or disposal; and
- proper disposal of products containing class I or II substances to minimize the release of the substance(s) into the environment.

#### **ARI 700 Purity Standards-Specifications for Fluorocarbon and Other Refrigerants**

Appendix A to Subpart F of Title 40 CFR Part 82 evaluates new, reclaimed, and/or repackaged refrigerants regardless of source, for use in new and existing refrigeration and air-conditioning products. More specifically, Appendix A dictates the acceptable purity levels of samples, based on the "Specifications for Fluorocarbon and Other Refrigerants," also known as the ARI 700 Standard. This standard characterizes both the contaminants and refrigerants by their physical properties; list methods and techniques by which to test the purity of refrigerants; and provides a detailed explanation of results and reporting procedures. Detailed test procedures are specified in the standard (see next section for more detail), to determine whether a refrigerant will be accepted or rejected for use. If deemed acceptable, the refrigerant is identified by its acceptable refrigerant number and/or its chemical name, and the source of the packaged refrigerant (i.e., manufacturer, reclaimer, or packager) is also identified (ARI 1993). The standard is intended to guide the industry, including manufacturers, refrigerant reclaimers, repackagers, distributors, installers, servicemen, contractors, and users (ARI 1999).

## ***Sampling and Reporting Procedures***

To identify the components of a refrigerant sample, both a liquid and a gas phase sample must be taken. Sampling precautions and specific techniques must be used to obtain an adequate sample. Once a sample is taken, each refrigerant addressed in the ARI 700 standard is identified by type through boiling point and/or gas chromatography tests. All editions of ARI 700 require specific testing apparatuses to perform the various purity tests. The following contaminants are classified in this section, and are identified through a variety of techniques using methods specified in Appendix C of ARI Standard 700:

- **Water content:** The Coulometric Karl Fischer titration test is used at room temperature for gas or liquid samples. The water content should not exceed the amount, in parts per million (ppm), specified in Tables 1A, 1B, and 1C of ARI 700.
- **Chloride:** Chloride testing is used to indicate the presence of HCl and/or other metal chlorides. The test used will show turbidity in the sample when chloride levels are about 3 ppm or greater, by weight. Any turbidity is reported as a "fail."
- **Acidity:** The acidity test uses titration techniques to detect any compound that ionizes as an acid. A sample mass of 100 to 120 grams is required. The maximum permissible acidity is measured as HCl and cannot exceed 1 ppm by weight.
- **High boiling residue:** High boiling residue is determined by measuring the residue from a set volume of refrigerant after evaporation. The sample is evaporated at room temperature or 113EF (140EF for R-113). The high boiling residue is expressed as a percentage by volume, and should not exceed the percent specified in Tables 1A, 1B, and 1C of ARI 700.
- **Particulates/solids:** A measured amount of sample is evaporated under controlled temperature conditions. The particulates/solids are determined by visual examination. Visual presence of dirt, rust, or other contaminants is reported as a "fail."
- **Non-condensables:** A vapor phase sample is used to determine the non-condensable gases in the refrigerant. A gas chromatography test with a thermal conductivity detector should be used to determine the non-condensable contaminants in the sample. The maximum level of non-condensables in the vapor phase cannot exceed 1.5 percent by volume at 75EF.

- **Volatile impurities including other refrigerants:** A gas chromatography test is used to determine the amount of volatile impurities, including other refrigerants. The sample should not contain more than 0.5 percent of contaminants by weight.

Once all components of a refrigerant are identified, the results must be reported. The manufacturer, reclaimer, or repackager of the refrigerant must characterize the sample by its refrigerant number or chemical name. The American National Standard Institute (ANSI) and the American Society of Heating Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 34 provides a concise system for designating numbers and providing safety classifications for refrigerants. The allowable levels of contaminants are listed in the tables within ARI 700.

### **EPA Certification**

Under the authority of CAAA §608, EPA has set requirements for reclaimers to become EPA-certified. The criteria are specified in Title 40, Part 82 §164 and §166 (g) and (h) of the CFR. Section 164 mandates that in order to sell refrigerant to a new owner, all reclaimers must comply with the following requirements:

- return the refrigerant to at least the standard of purity set forth in Appendix A to Subpart F of Part 82;
- verify that the refrigerant has been brought to the indicated purity levels by using the methodology presented in Appendix A;
- release no more than 1.5 percent of the refrigerant during the reclamation process;
- dispose of wastes from the reclamation process in accordance with all applicable laws and regulations; and
- submit the name, address, and a list of equipment used by the reclaimer to the §608 Recycling Program Manager along with a signed certification of adherence to all of the above rules. Certificates are not transferable, and all changes in ownership must be reported within 30 days of the change in ownership status. Failure to abide by these rules may result in revocation or suspension of the reclaimer's rights to operate.

In addition to the previously stated requirements, §166 (g) and (h) mandate that reclaimers maintain records

of the names and addresses of all persons sending them material for reclamation and the quantity of the material (both refrigerant and contaminant). All information must be reported to the EPA annually, within 30 days of the end of the calendar year.

Reclaimers may also become certified by ARI. The technical standards developed and published by ARI establish criteria and procedures for measuring and certifying refrigerant purity. Participation in the program is voluntary (and is open to non-ARI members on an equal basis) and allows refrigerant buyers and users to properly make selections for specific applications. In this certification program, ARI annually selects a significant portion of reclaimed refrigerants from each manufacturer to be tested by an independent laboratory under contract to ARI. Samples are randomly selected to ensure that they meet the manufacturer-certified purity specifications of ARI 700. A test failure requires cessation of product reclamation until the specifications can be met (ARI 2000).

### **EPA List of Certified Reclaimers**

A list of EPA-certified reclaimers is provided in Attachment 1. In order to sell used refrigerant, reclaimers must be EPA-certified. If a reclaimer wants to be included in EPA's list of certified reclaimers, the following information must be submitted:

- whether only refrigerant that has been recovered from appliances by company employees may be reclaimed, or if used refrigerant from outside technicians and contractors is accepted;
- contact name and telephone number for the public; and
- states or metropolitan areas from which used refrigerant is accepted.

### **Reclamation Process**

The refrigerant reclamation process involves the removal of particulates, oil, organic and chlorinated acids, moisture, and non-condensable gases in order to achieve standards as specified by ARI 700. To remove particulates, oil, acids, and moisture, refrigerant is typically distilled through a battery of filters and dryers. The refrigerant is then pumped into a separate processing system that super cools the refrigerant below its boiling point, and non-condensable gases (oxygen and nitrogen) are safely vented to the atmosphere. The refrigerant is then run through a battery of laboratory tests to ensure that it meets ARI Standard 700. If the refrigerant does not meet the standard, the above reclamation procedures are repeated until the standard is achieved (Richard Marcus 2000).

Often used refrigerants become cross-contaminated in the field, or may be patented blends of two or more refrigerant types. To reclaim cross-contaminated or mixed refrigerant, an additional step is performed following the above procedures. Individual refrigerant types are separated either by a destruction-based technique which destroys one of the chemical components of the mixture, or by a process called fractional distillation, which manipulates pressure and temperature to boil off and recapture components (Richard Marcus 2000; Liberty Technology 2000). After cycling through the separation process, individual refrigerants are tested to determine if they meet ASHRAE Standard 34 composition specifications. Refrigerants are recycled through the separation process until their composition meets the standard requirements (for a flow chart summary of the full reclamation process, see Attachment 2). High-speed and large-capacity technologies now exist to separate almost any refrigerant mixture. Companies are developing improved processes that can separate a variety of refrigerants and contaminants, such as removing vinyl chloride from R-12 (aerosol sector); separation of R-12 from R-134a; and any mixture containing CFC, HFC, or HCFC components (Liberty Technology International 2000; Hudson 2000; Andrews 2000). Still, however, refrigerant types that form azeotropes<sup>1</sup> or have similar properties may be very costly or impossible to separate (Richard Marcus 2000). Attachment 3 summarizes the amount of refrigerant reclaimed in 1999 by type of refrigerant.

Reclamation costs generally range from \$1.00 to \$2.50 per pound for most CFC, HCFC, and HFC refrigerants that are not cross-contaminated or mixed (Richard Marcus 2000; Romine 2000; McCormick 2000). The more contaminated the refrigerant, the more costly the reclamation, as additional processing treatments are needed. For mixed or cross-contaminated refrigerant, reclamation is more expensive because of the additional separation and testing procedures involved (Richard Marcus 2000). The costs to reclaim mixed refrigerant is approximately \$4 or \$5 per pound (Romine 2000; Schmierer 2000), and may be higher for blends that are more difficult to separate. Reclamation costs increase with each additional separation process that refrigerants undergo (Richard Marcus 2000). Cost may also increase for the reclamation of patented refrigerant blends, as law requires reclaimers to obtain manufacturer consent to reconstitute the blend and restore its proportional composition (Mandrachia 2000). For mixtures that form azeotropes or have similar properties, reclamation may be not be economically feasible (depending on the market value of the particular refrigerant), and destruction may be necessary (Richard Marcus 2000).

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<sup>1</sup> An azeotropic mixture is a blend of two or more components of different volatilities that do not change volumetric composition or saturation temperature as they evaporate or condense at constant pressure (ASHRAE 1992). As such, an azeotropic blend behaves like a single substance, with a single boiling point that may be higher or lower than that of any of its individual components (Sax and Lewis 1987). R-500 and R-502 are examples of azeotropic blends.

## **Destruction Technologies**

Destruction refers to the disposal of used refrigerants. Refrigerant destruction is necessary when refrigerants have become contaminated in such a way that current reclamation techniques will not work (e.g., proprietary blends, mixed refrigerants with very similar chemical properties, or lack of access to reclamation facilities). The technology typically used to commercially destroy refrigerants in the United States is known as a high-temperature rotary kiln incineration. Rotary kilns have a limited capacity to handle halocarbons, and refrigerants must therefore be trickle-fed into the incinerators and mixed with other compatible waste, such as oils (this process is known as fuel-blending). Trace amounts of halocarbons may be released to the atmosphere, and the ash that is produced, which is considered hazardous waste, is typically landfilled (Tucker 2000; Richard Marcus 2000). In addition to this type of incineration, there is one facility in the U.S. that destroys refrigerant by means of a fluidized bed incinerator. This technology provides for more complete combustion at a lower temperature and reduces the potential for dioxin emissions. Only water and ash are released into the atmosphere, and the ash that is generated from the system is not hazardous (Tucker 2000).

Another advanced destruction method is plasma arc technology. This technology uses thermal plasmas as the heat source to degrade refrigerant, instead of combustion. Unlike conventional incinerators, plasma systems can deal with a full load of halocarbons (they do not have a limited capacity like incinerators), without releasing any pollutants into the atmosphere (Richard Marcus 2000; Forner 2000). This technology uses higher temperatures, shorter residence times, and separation of the heat source from the waste being destroyed (Murphy 1999). The system directly injects refrigerants under pressure as a vapor into a 10,000EC plasma arc (created by the discharge of a large electric current between a separate cathode and anode in the presence of argon). The molecules are then mixed with this hot plasma and almost instantaneously converted into their constituent atoms and ions by a process known as pyrolysis. The ionized gas is then cooled as it passes through a reaction chamber, and is rapidly quenched below 100EC. Finally, a dilute aqueous mixture containing four harmless salts and a small quantity of gaseous atmospheric discharge (comprised of approximately 50 percent carbon dioxide and 50 percent argon by volume) are the waste streams. The waste is then neutralized and managed accordingly, with nothing being released into the atmosphere (Forner 2000). This process is capable of destroying halons and CFCs for a destruction and removal efficiency of greater than 99.999 percent (Dascem Holdings Pty Ltd. 2000). This technology is currently in use in Australia (patented as PLASCON<sup>TM</sup>), where some U.S. stock is sent for destruction (Richard Marcus 2000). Procedures are underway to construct a large-capacity plasma system in the U.S. some time in 2001 (Forner 2000).

Additionally, negotiations are currently underway in the U.S. to raise funds to build a prototype of yet another new destruction technology, known as vitrification (Schwartz 2000a). The vitrification process converts refrigerants into glass by destroying halogenated organic materials through the dissociation of the halogen molecule(s) and conversion of the carbon portion through pyrolysis. The entire spectrum of CFCs, HCFCs, and halons are encapsulated and immobilized into a chemically resistant and durable rough glass frit that can be further manufactured into a commercially viable product. The system operates at constant high temperatures between 1000EC to 1750EC, to ensure destruction and prevent the reformation of complex pollutants. Virtually no secondary waste is produced, as gas is scrubbed and recycled back to the glass melter (Schwartz 2000b).

Based on information gathered from refrigerant destruction and reclamation companies, the major players in the business of refrigerant destruction are Ensco Inc., Clean Harbors Environmental Services, Inc., Rineco Total Waste Management, Ross Incineration Services, Inc., and Safety Kleen, Inc. (see Attachment 4) (Richard Marcus 2000; Tucker 2000). These companies all operate facilities that are permitted to handle hazardous waste. This is because, unlike refrigerant sent for reclamation, refrigerants destined for destruction may be subject to RCRA hazardous waste codes. Subpart C of Part 261 specifies that solid wastes exhibiting properties of ignitability (code D001), corrosivity (D002), reactivity (D003), and/or toxicity (D004), are classified as hazardous. Typically, refrigerants do not exhibit characteristics of corrosivity or reactivity, but some do exhibit characteristics of ignitability and/or toxicity. ASHRAE Standard 34 classifies refrigerants by flammability and toxicity (see Attachment 5). For flammability, Standard 34 assigns refrigerants to one of three classes: Class 1 for non-flammable refrigerants; Class 2 for refrigerants with lower flammability limits; and Class 3 for refrigerants that are highly flammable. Similarly, Standard 34 assesses toxicity status by coding refrigerants as Class A for when toxicity has not been identified at concentrations less than or equal to 400 ppm, and as Class B when there is evidence of toxicity at concentrations below 400 ppm. For example, R-123 is classified B1 (toxic but not flammable), and R-142b is classified as A2 (non-toxic with a lower flammability limit). For zeotropic<sup>2</sup> blends, whose flammability and/or toxicity characteristics may change as the composition changes, a dual classification is assigned (classifications are separated by a slash). The first classification listed is the classification of the composition of the blend as formulated, and the second classification listed is the classification of the blend composition at the worst case of fractionation<sup>3</sup> (ASHRAE 1992). For example, non-hazardous R-401A is classified as A1/A1, signifying that the blend is non-toxic and non-flammable both in its formulated

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<sup>2</sup> Zeotropic blends are blends composed of multiple components of different volatilities that change volumetric composition and saturation temperatures when evaporated or condensed at constant pressure (ASHRAE 1992).

<sup>3</sup> Fractionation is the process by which the composition of a blend is changed by preferential evaporation of the more volatile component(s) or by condensation of the less volatile component(s) (ASHRAE 1992).

composition and in its worst case of fractionation. If refrigerants are not classified in ASHRAE Standard 34, it is the responsibility of the owner to establish the refrigerant group and ensure that it is properly labeled and treated.

Reclaimers typically pay between \$1.50 and \$2.00 per pound to have non-reclaimable refrigerant destroyed (including transportation and storage costs) (Richard Marcus 2000; Ron Marcus 2000; Romine 2000; Berger 2000). Refrigerant destruction costs could range as high as \$5 per pound depending on quantity, Btu value, and on the capacity of the incinerator at any given time (i.e., if an incineration facility has a large amount of refrigerant to destroy in a given week, prices may increase or the facility may even refuse to accept the waste) (TWI 2000; Richard Marcus 2000; Sample 2000).

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**TOTAL QUANTITY RECLAIMED BY REFRIGERANT (lbs)**

	R-11	R-12	R-13	R-22	R-23	R-113	R-114	R-123	R-134a	R-142b	R-401A	R-402A	R-404A	R-500	R-502	Miscellaneous	TOTAL
<b>Totals</b>	1,605,550	2,040,080	234	6,116,802	23	204,355	191,559	187,294	456,756	15,100	11,620	14,445	1	202,213	824,520	16,105	<b>11,870,552</b>

Note: the miscellaneous category includes 2,315 lbs of HFC-236fa, 8,800 lbs lithium bromide solution, and 4,990 lbs of 400 series and others

## Total Amount of Refrigerant Reclaimed in the United States in 1999 (lbs)

